Micro Device and Microfluidic Fabrication with Synchrotron Lithography

Pattanaphong Janphuang, Ph.D.

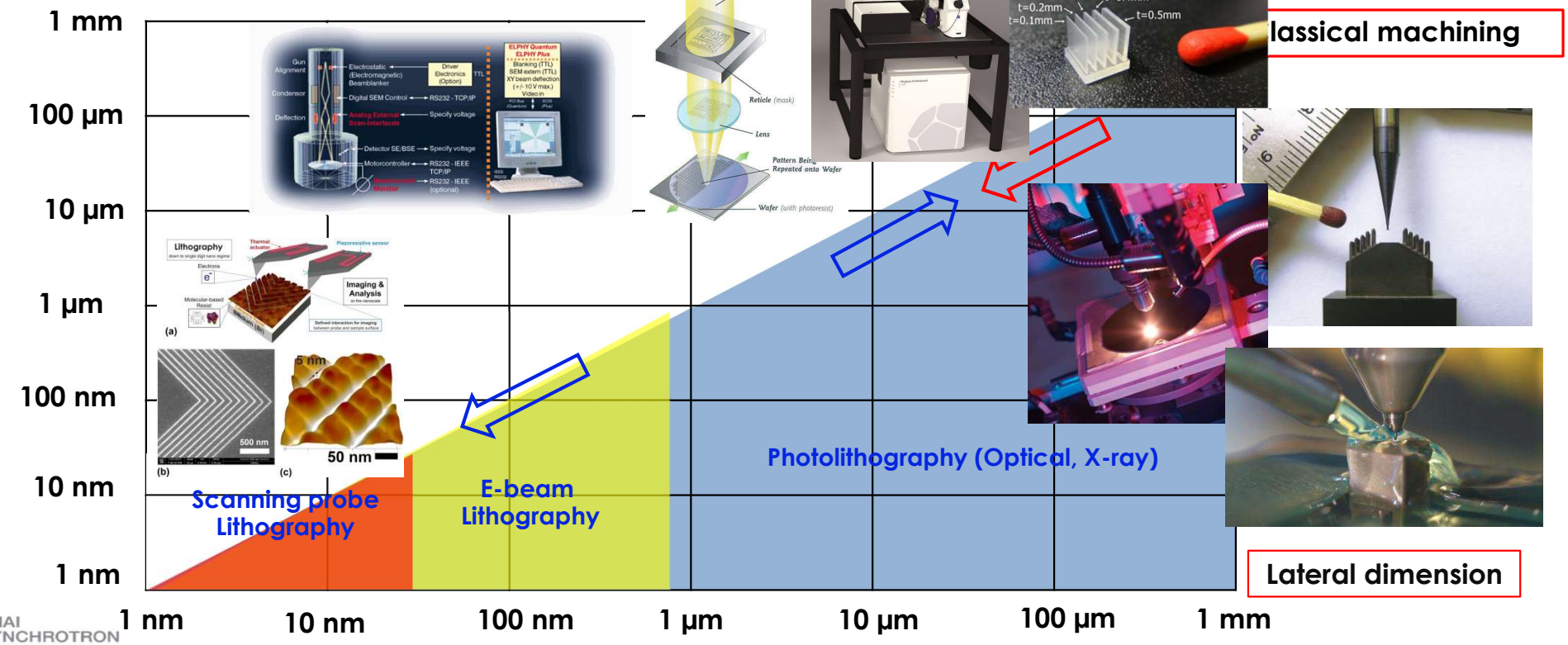
Chief, Technical and Engineering Development Division

Synchrotron Light Research Institute (Public Organization)

Microfabrication (machining)

Microfabrication – a process of fabricating mechanical components and benefits of the properties linked to small dimensions (in the **micron** to **millimeter** size range)

Major techniques for defining lateral dimensions



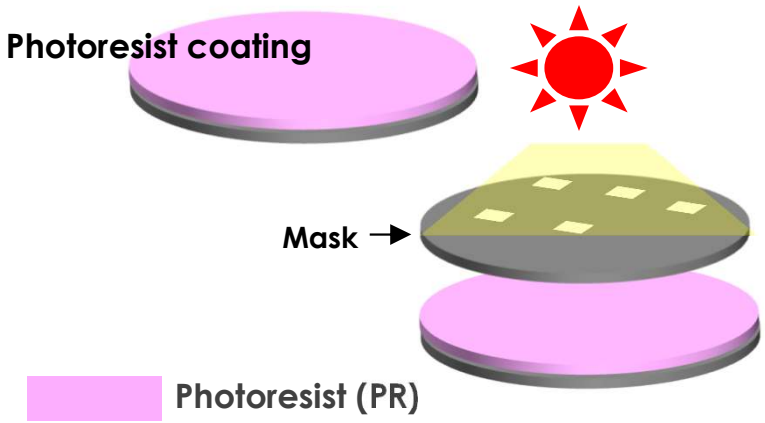
Concept of micropatterning

Photolithography: image transfer process of the device geometry (microstructure or MEMS devices) onto wafer / thin film using light

Lithography – from Greek

Lithos = rock

Gráphein = write



- ✓ Memorise the image
- ✓ Protection during the transfer of image
- ✓ Temporary layer (can be removed)

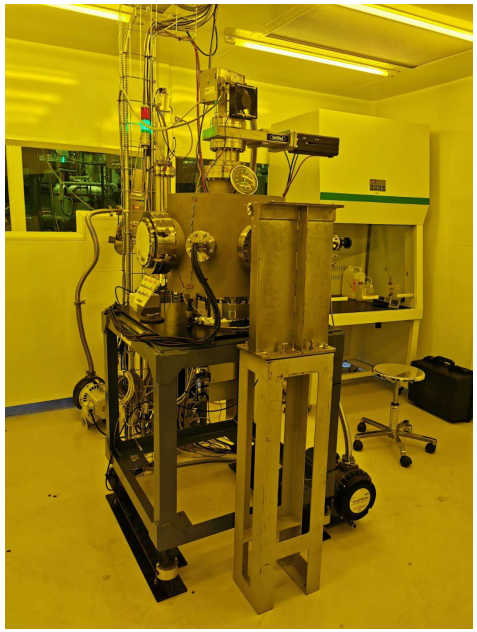
The Photolithography

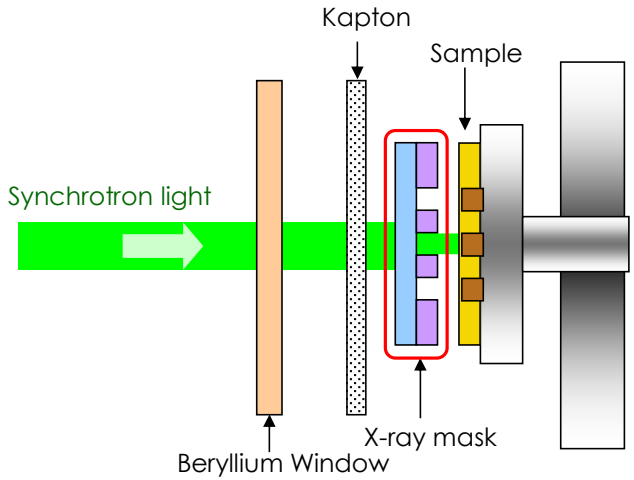
- ❑ Yields all the dimensions of the device / chip
- ❑ 35% of chip (IC's) or device cost !!!

(Currently, at high resolution going up to 70%)

Deep X-ray lithography

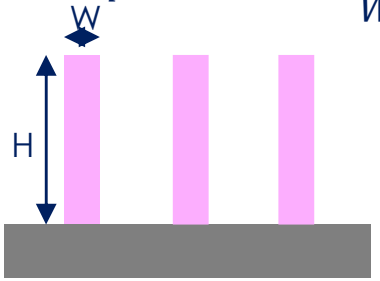
- X-ray from Synchrotron

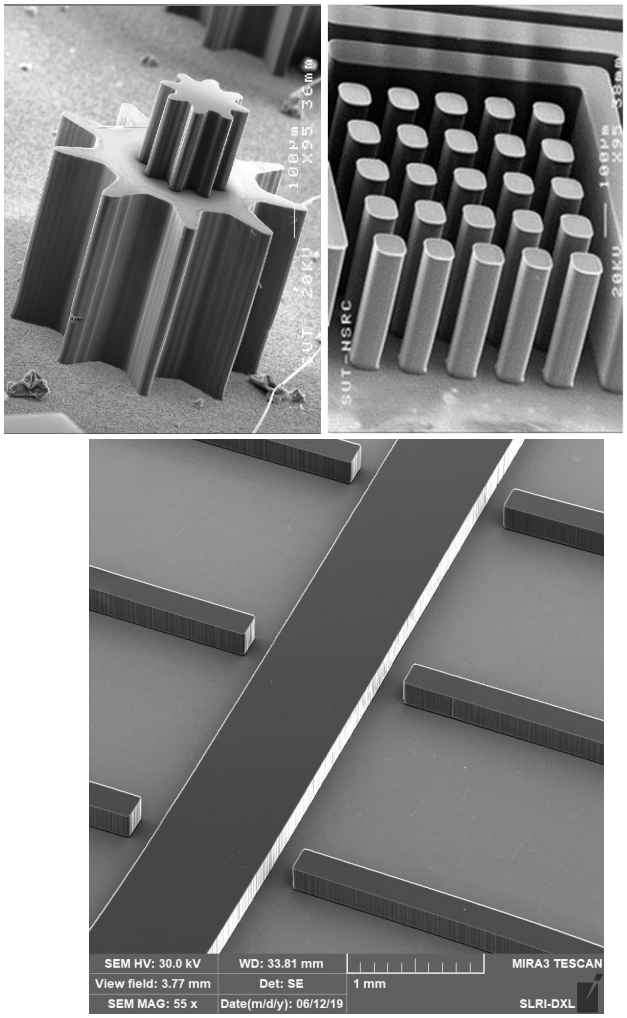




Schematic diagram of X-ray exposure process

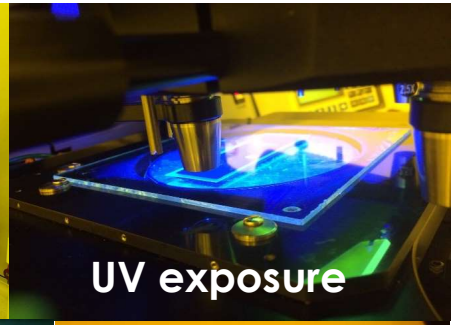
$$Aspect\ ratio = \frac{H}{W}$$

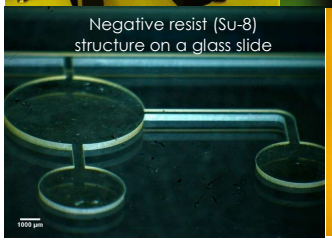


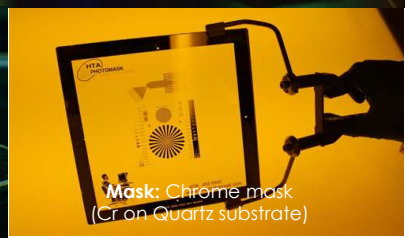


Other lithography

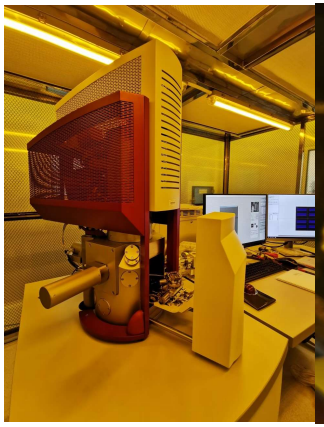
❑ UV lithography

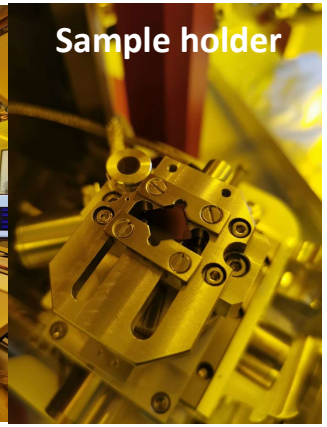


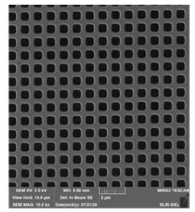


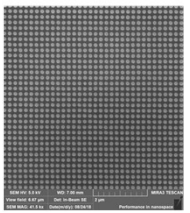


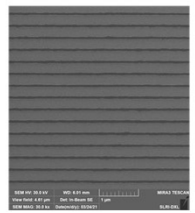
❑ Electron beam lithography







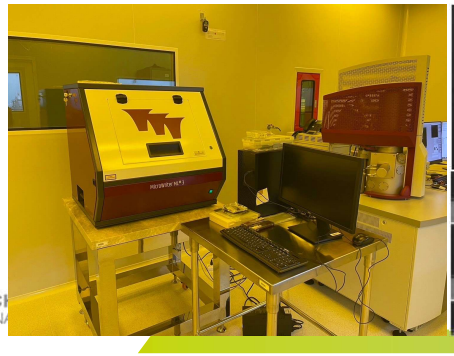


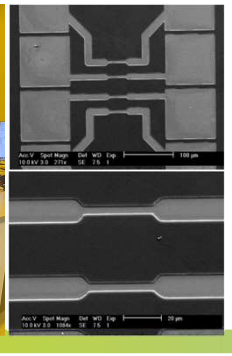


Specification for EBL

- Electron beam energy: 200eV – 30keV
- Maximum sample size: 2.5x2.5 cm
- Maximum write field size: 1 mm
- Error of write field (WF) accuracy: 1% of WF size
- Designing software: DrawBeam and Clewin (.gds, .dxf, .dbp)
- Probe current: 2pA to 200 nA
- Maximum sample size: 2.5x2.5 cm
- The error stage movement: ±2 μm

❑ Direct-write optical lithography

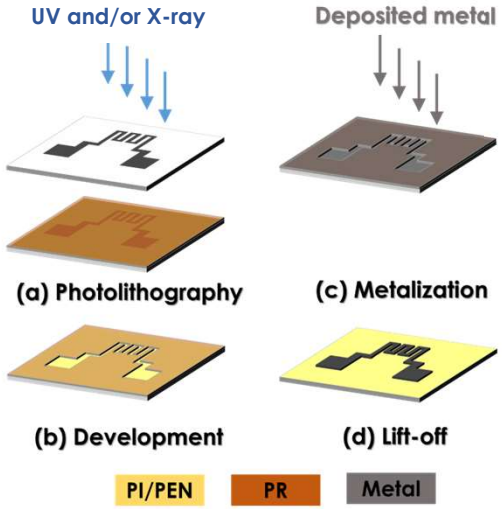




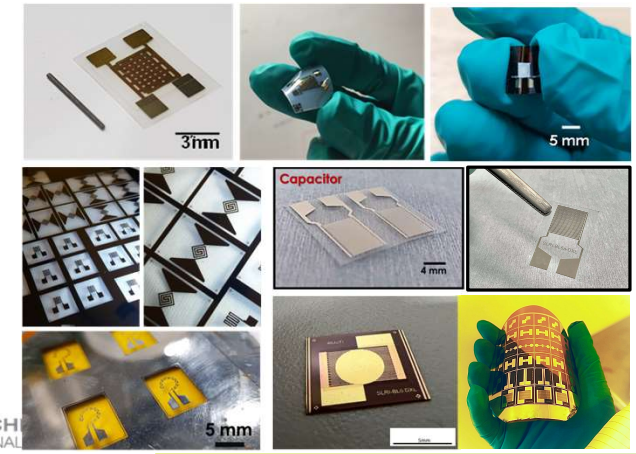
Key features

- 195mm x 195mm maximum writing area.
- 230mm x 230mm x 15mm maximum wafer size.
- 0.6μm, 1μm, 2μm and 5μm minimum feature sizes across the full writing area. 0.4um minimum feature size available as an option.

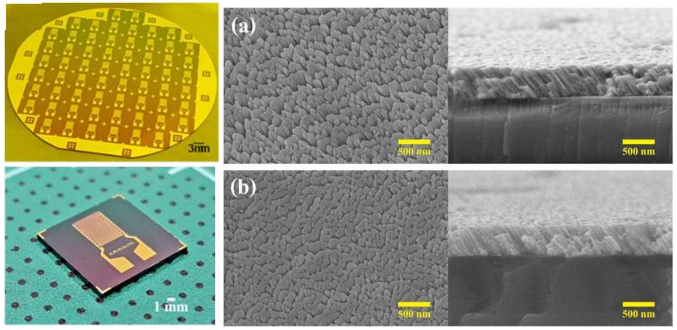
Gas sensing application

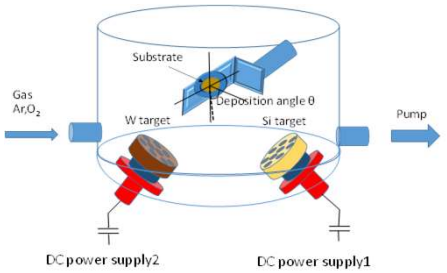


Low-cost fabricated sensors on plastic foil, disposal, reusable, wearable applications !!!

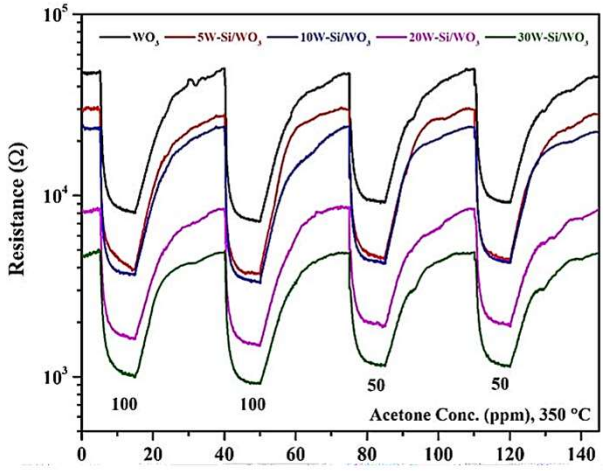


Acetone gas sensor based on Si-doped WO_3 nanorods prepared by magnetron co-sputtering



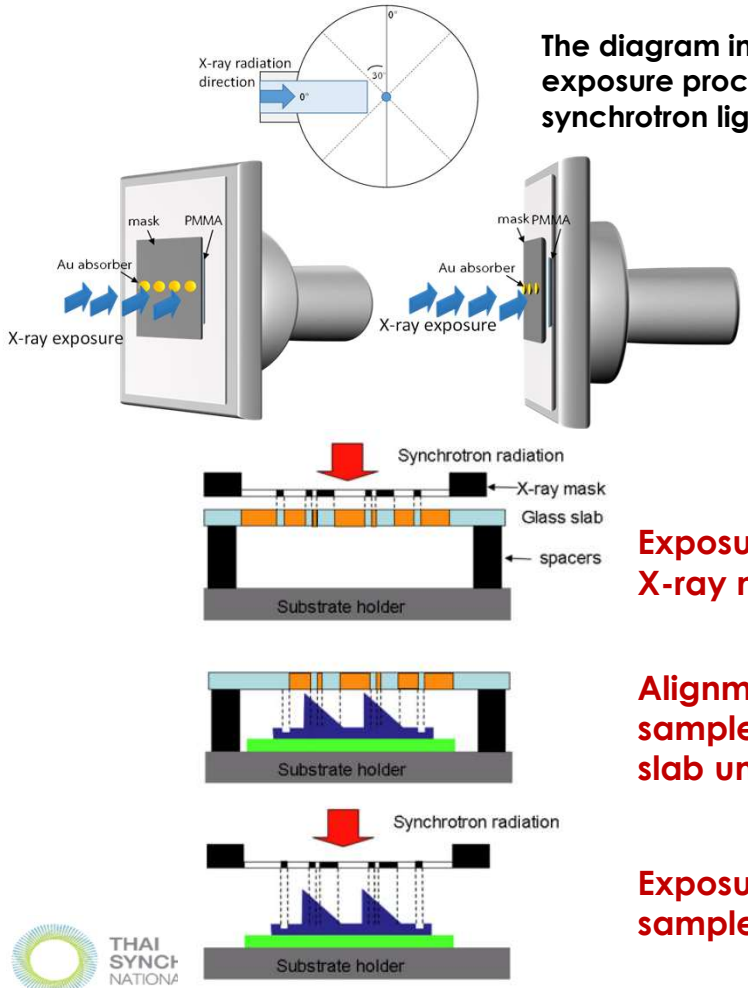


SEM images of (a) pure WO_3 and (b) Si-doped WO_3 nanorods deposited onto the sensor substrate after annealing



- The potential of high-sensitivity acetone gas sensor at low concentration
- an effective tool for diabetes non-invasive monitoring

Microneedle arrays fabricated by Deep X-ray lithography

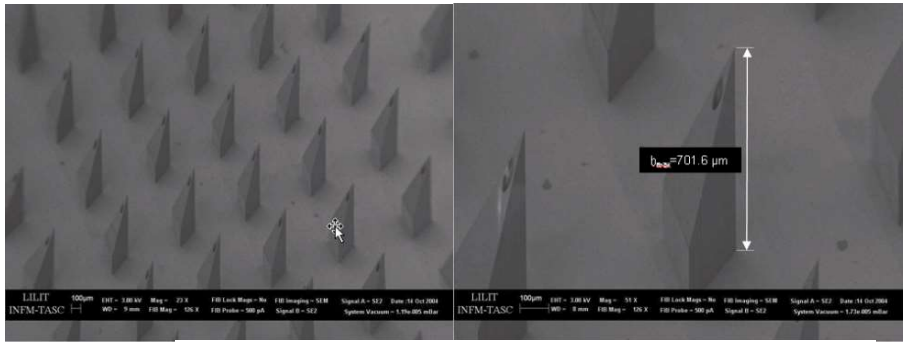


The diagram indicates the X-ray exposure process using synchrotron light

Exposure of glass slab through X-ray mask

Alignment of the sawtooth sample with the exposed glass slab under the microscope

Exposure of aligned sawtooth sample through the X-ray mask



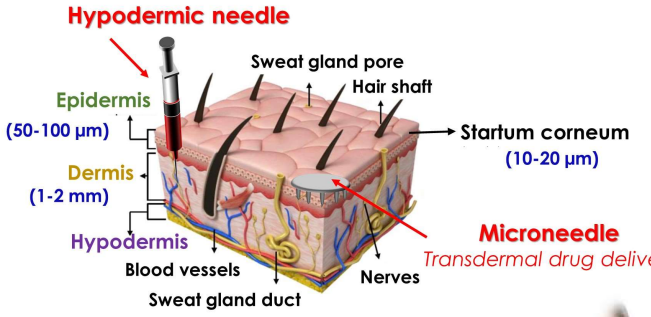
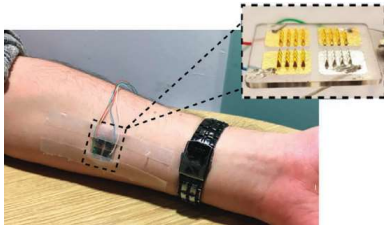


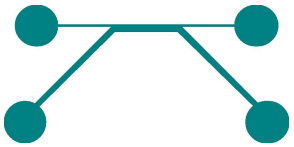
Fig. 1 *Illustrated of needle in human skin*



Medical

Aesthetic enhancements

Fabrication of master mould for microfluidics

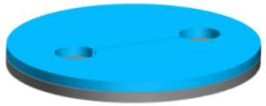


In collaboration with SUT

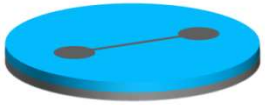
"Sperm sorting using microfluidics device"

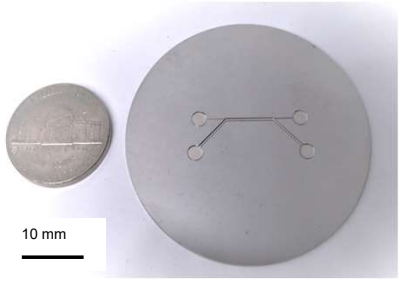
SUT-SLRI-BL6a:DXL

Image transfer (Photolithography)

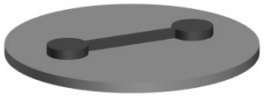


Ni electrodeposition





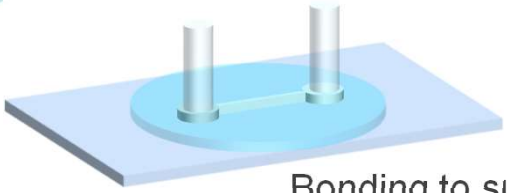
PR stripping



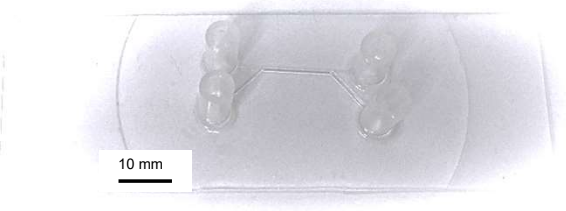
Soft-lithography (Replicated by elastomer)

Casting PDMS on the master

Peel off

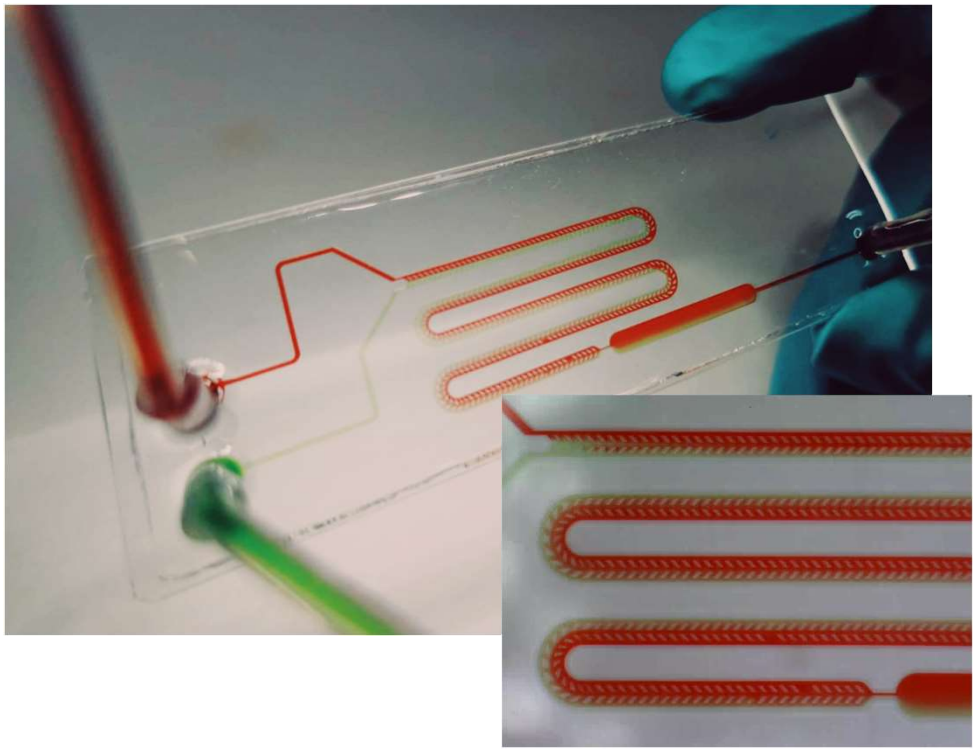


Bonding to substrate

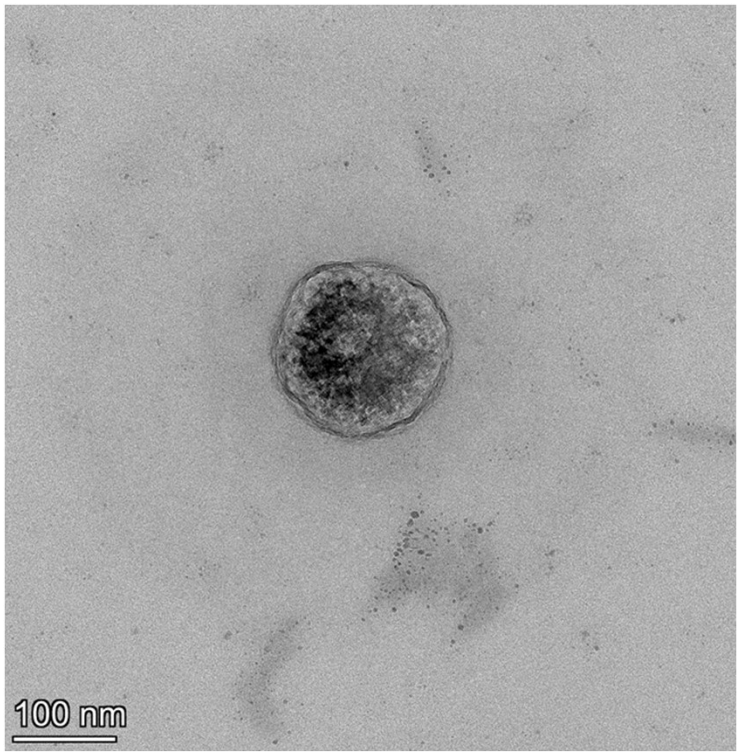


SUS | PR | Ni | PDMS | SiO_2

Synthesis of lipid nanoparticles by microfluidics

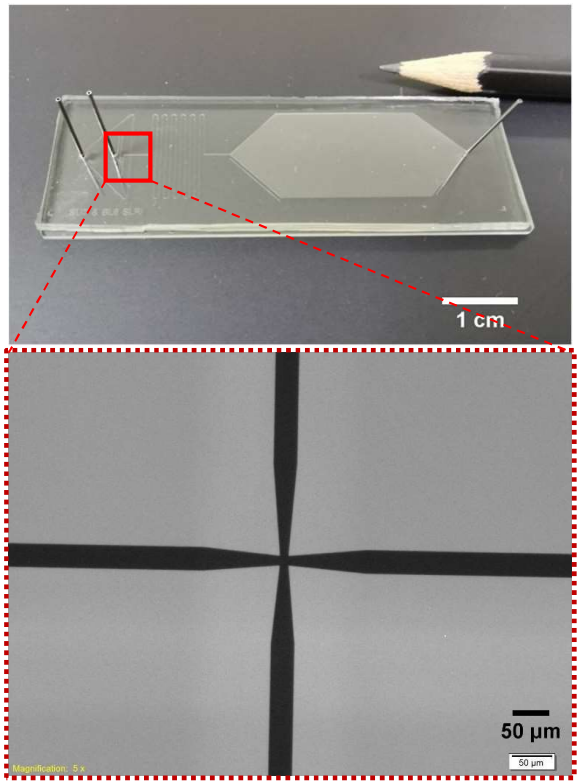


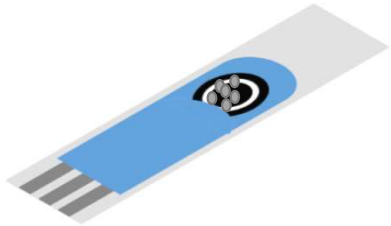
Micromixer fabricated using X-ray lithography & Soft lithography for synthesis of lipidnanoparticles

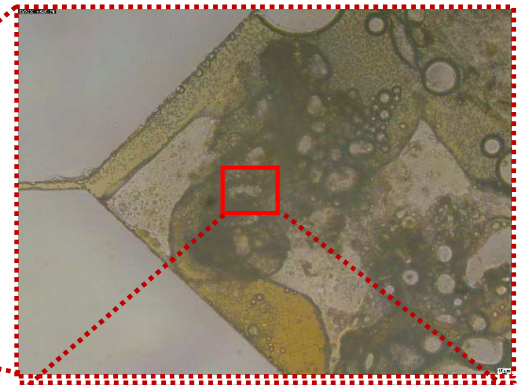


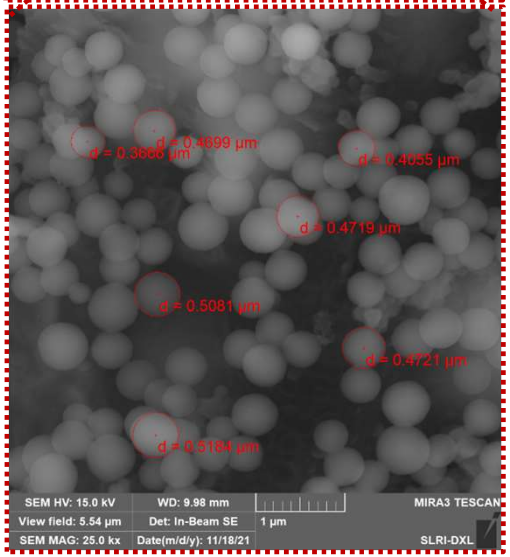
TEM of Lipidnanoparticles synthesized by fabricated micromixer

The polypyrrole chemistry developed with microfluidic encapsulation





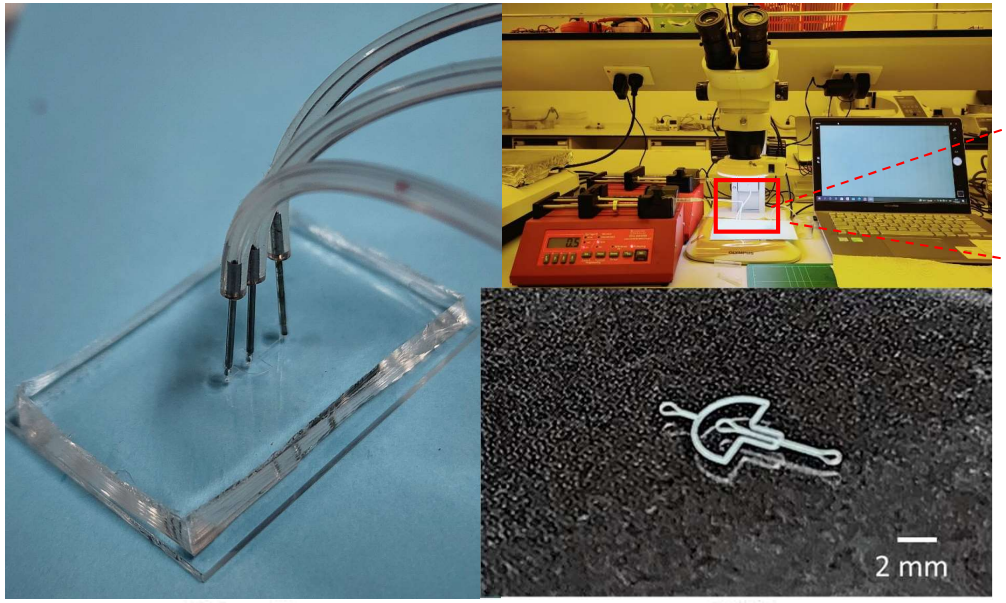


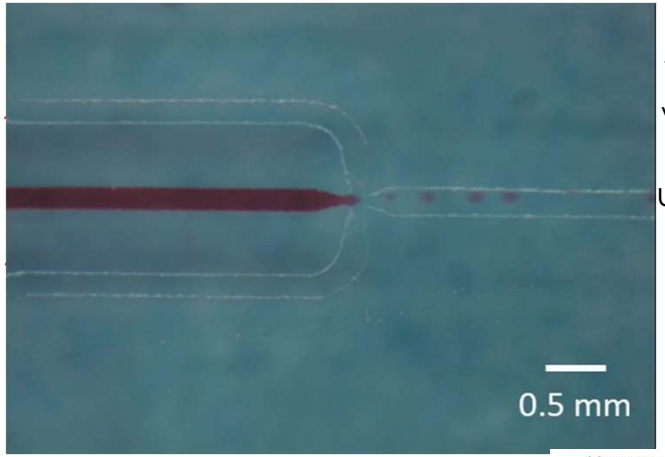


Polypyrrole capsules (10-micron channel)
amount loading 0.2 mg

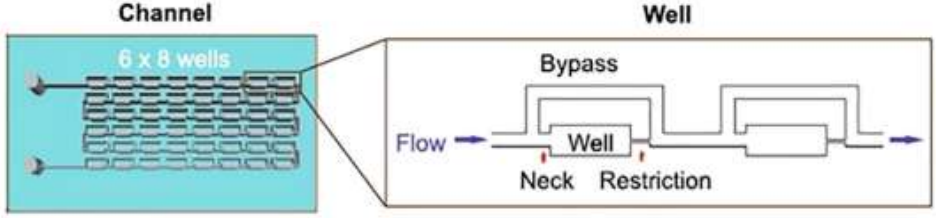
The microchannel widths 10 µm, high 50 µm and using flow rate of Pyrrole 0.4 µL/min : $FeCl_3$ 0.10 µL/min

Synthesis of microdroplet

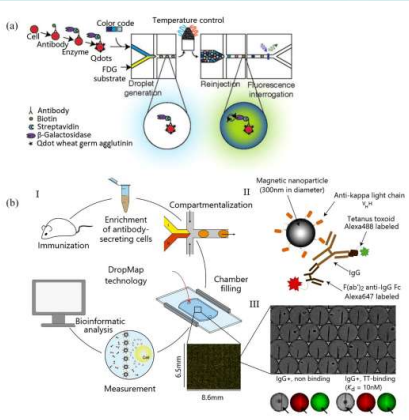




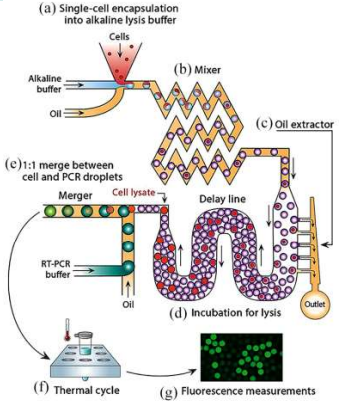
The microchannel widths are 150 µm, high 100 µm and using a flow rate of oil 20 µL/min: red water 2 µL/min



Drug screen of tumor cells

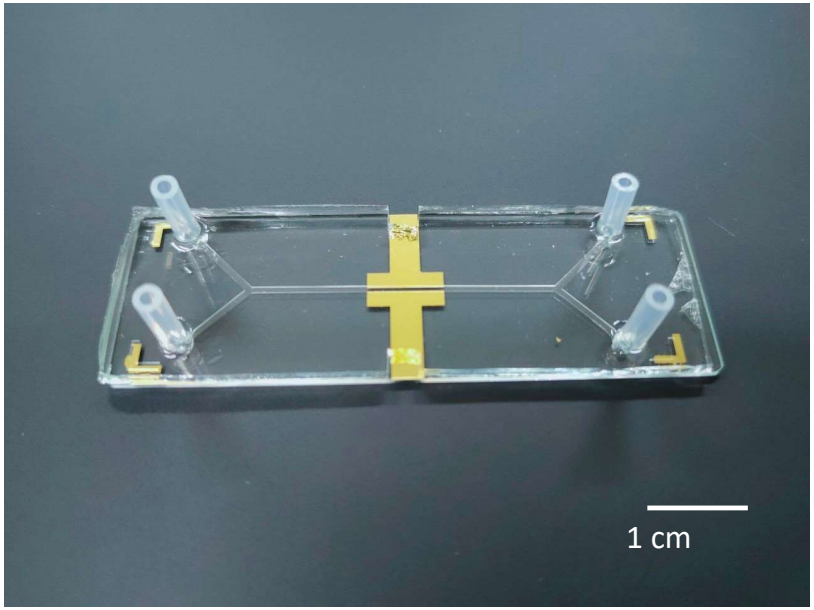


Cell recognition

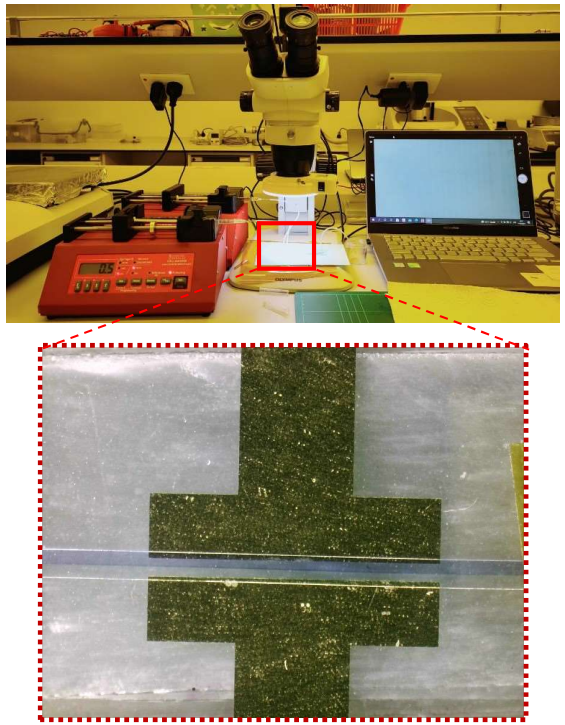


Single-cell RT-PCR

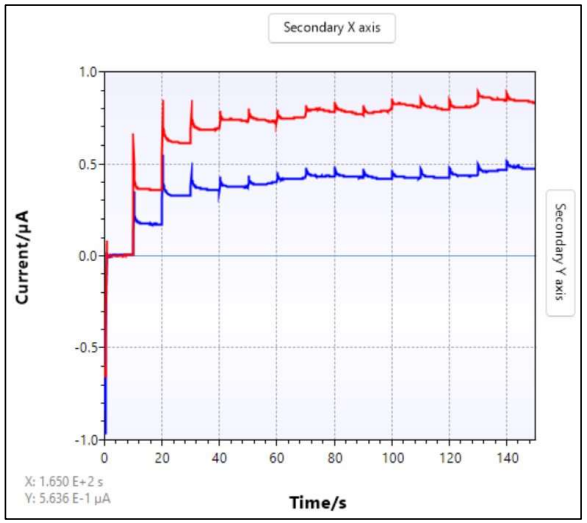
The biofuel cell



The microchannel widths are 1 mm, high 100 μm and using a flow rate of catholyte 200 μL/min and 500 μL/min: anolyte 200 μL/min and 500 μL/min

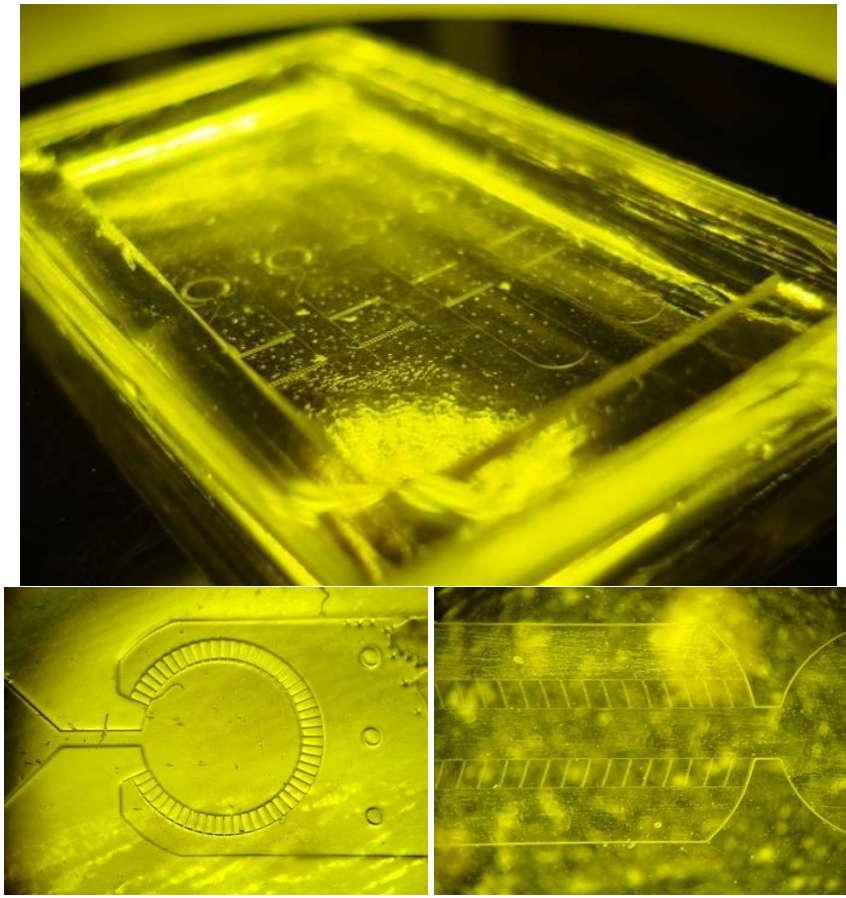


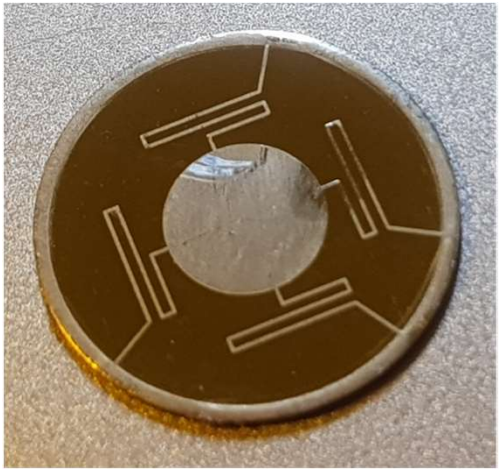
The catholyte and anolyte solution



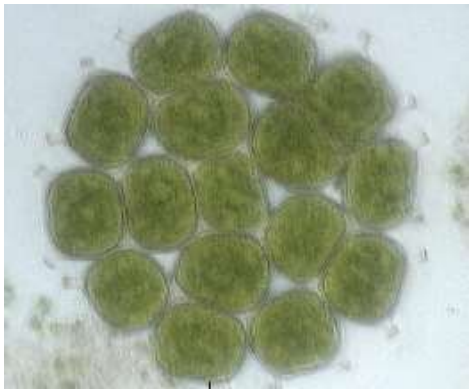
Potential with current curves

Other microfluidic devices

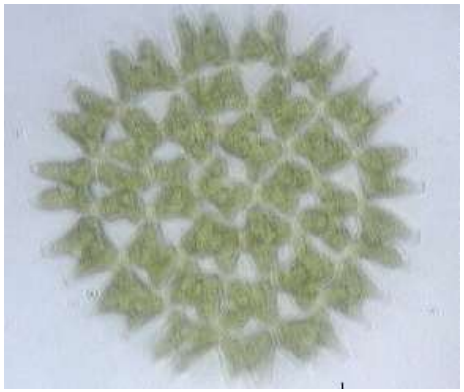




Ni based μ-fluidic chips on CaF_2 window



Pediastrum duplex in JM media



Pediastrum duplex in BG11 media

THANK YOU

SYNCHROTRON THAILAND CENTRAL LAB

Fabrication of Gunshot Residues (GSR)

The GSR pattern by **EBL**

Thin film of **Pb**, thick ~300 nm by rate 22.16 nm/min with at 75 W

Thin film of **Sb_2O_3** , thick ~300 nm by rate 9.68 nm/min with at 75 W

Thin film of **$BaTiO_3$** , thick ~300 nm by rate 3.79 nm/min with at 100 W

Lift-off to remove resist and LOR5B using PG remover